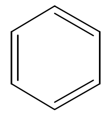
BENZENE
CAS No. 71-43-2

First Listed in the *First Annual Report on Carcinogens*



CARCINOGENICITY

Benzene is *known to be a human carcinogen* based on sufficient evidence of carcinogenicity in humans (IARC V.29, 1982; IARC S.4, 1982). Many case reports and case series have described the association of leukemia with exposure to benzene, either alone or in combination with other chemicals. Most cases were acute myelogenous leukemia, although some were monocytic, erythroblastic or lymphocytic, and some lymphomas have been noted. Two follow-up studies showed high incidences of leukemia among individuals ascertained as cases of benzene hemopathy. A series of epidemiological studies, both cohort and case-control, showed statistically significant associations between leukemia (predominantly myelogenous) and occupational exposure to benzene and benzene-containing solvents. These results were replicated in a number of countries and different industries. In the epidemiological studies of people exposed primarily to benzene, statistically significant excesses of leukemia were observed.

An IARC Working Group reported that there is sufficient evidence of carcinogenicity of benzene in experimental animals (IARC V.29, 1982; IARC S.7, 1987; NTP 289, 1986). When administered by gavage, benzene increased the incidences of Zymbal gland carcinomas and oral cavity papillomas and carcinomas in rats of both sexes, as well as skin carcinomas in male rats. When administered by gavage, benzene increased the incidences of Zymbal gland carcinomas, malignant lymphomas, and alveolar/bronchiolar adenomas and carcinomas in mice of both sexes; harderian gland adenomas and carcinomas of the preputial gland in male mice; and ovarian granulosa cell tumors and benign mixed tumors and mammary gland carcinomas and carcinosarcomas in female mice (NTP 289, 1986).

PROPERTIES

Benzene is a colorless, volatile, flammable liquid with an aromatic odor. It is slightly soluble in water and is miscible with alcohol, ether, chloroform, acetone, carbon tetrachloride, carbon disulfide, oils, and glacial acetic acid.

USE

Benzene, an industrial chemical, is a major raw material used extensively as a solvent in the chemical and drug industries, as a starting material and intermediate in the synthesis of numerous chemicals, and as a gasoline additive. Approximately 80% of the benzene consumed is used to produce ethylbenzene (55%), cumene (21%), cyclohexane (14%), aniline (5%), and miscellaneous other compounds (5%) (Chem. Mktg. Rep., 1986). It was used alone or in formulations for screwworm control in animals and as an ingredient of grain fumigants, but its pesticidal uses have also been canceled (HSDB, 1997).

PRODUCTION

The vast use of benzene has ranked the chemical in the top 20 highest volume chemicals produced in the United States for the past several years by *Chemical and Engineering News*. Although there have been a few decreases in output, the percent annual change has been positive. Production of benzene has increased from 1.6 billion gal in 1980 to 2.3 billion gal in 1997. In addition the average yearly import of benzene was 0.3 billion gal during this time period. From 1987 to 1997 the percent change was 4 (Chem. Eng. News, 1998). The production figures from 1987 to 1997 do not reflect benzene obtained from the fractional distillation of the light oil formed as a by-product in the high-temperature destructive distillation of coal in coke production. Coke oven benzene has accounted for less than 5% of total U.S. output for several years (Chem. Prod., 1988; Chem. Eng. News, 1998). Benzene is expected to remain one of industry's most important chemicals.

EXPOSURE

The primary routes of potential human exposure to benzene are inhalation and dermal contact, with the former being the dominant pathway, accounting for more than 99% of the total daily intake. Exposure via inhalation occurs not only of contaminated air but also of tobacco smoke, from both active and passive smoking. About half of the total national exposure to benzene comes from cigarette smoke, with levels in mainstream smoke ranging from 5.9 to 7.3 μg/cigarette and those in sidestream smoke ranging from 345 to 653 μg/cigarette. Contaminated air occurs mainly in areas of heavy motor vehicle traffic and around gas stations, since benzene is a constituent of auto exhaust and fuel evaporation (ATSDR, 1997-K007). Outdoor environmental levels up to 349 $\mu g/m^3$ in industrial centers with a high density of automobile traffic have been measured; in remote rural areas levels up to 0.2 $\mu g/m^3$ have been recorded (IPCS, 1993). For late model cars, it has been estimated that more than 90% of automotive benzene comes from exhaust and less than 10% from fuel evaporation (HSDB, 1997).

The Environmental Protection Agency (EPA) estimates benzene emissions from pharmaceutical, plastics, resin, and rubber plants at 495 million tons per year. Its new, far more stringent standards for benzene call for reducing current benzene emissions by 97% at storage tanks and coke by-product recovery plants. The EPA proposes that emissions from those sources be cut by 94 tons/year through the use of carbon absorbers and incinerators. The new rules will lower total industrial emissions of benzene by 90%. According to the EPA, half the U.S. population is exposed to benzene from industrial sources and virtually everyone in the country is exposed to benzene in gasoline. Benzene is a known carcinogen and has been linked to leukemia but for the majority of the population, the cancer risk is low, according to EPA (Chem. Week, 1989). The EPA now estimates that three people die annually from cancer caused by exposure to benzene emissions (Chem. Mktg. Rep. 1989). The Toxic Chemical Release Inventory (EPA) listed 471 industrial facilities that produced, processed, or otherwise used benzene in 1988 (TRI, 1990). In compliance with the Community Right-to-Know Program, the facilities reported releases of benzene to the environment, which were estimated to total 29.2 million lb. In the 1993 inventory, estimated atmospheric emissions from manufacturing and processing facilities were lower—10.2 million lb (ATSDR, 1997-K007). In 1989, EPA estimated that the largest industrial source was coke oven emissions (17,000 metric tons/year) (ATSDR, 1997-K007). Estimates indicate that possibly 800,000 persons may be exposed to benzene from coke oven emissions at levels greater than 0.1 ppm (see Coke Oven Emissions, Section III.A); 5 million persons may be exposed to benzene from petroleum refinery emissions at levels of 0.1 to 1.0 ppm. However, information on the levels of benzene in the atmosphere is limited. Ambient monitoring data indicate that levels of benzene range from 1 to 100 ppb. The highest values were reported in metropolitan areas (IARC V.29, 1982).

Additionally, benzene has been identified in drinking water and in subsurface water at concentrations up to 10 ppm. Benzene occurs in fruits, fish, vegetables, nuts, dairy products, beverages, and eggs. NCI estimated that an individual may ingest up to 250 µg/day (OSH, 1982). Therefore, water and food-borne benzene are a small contribution to the total daily intake in non-smoking adults (between about 3 and 24 µg/kg body weight per day) (IPCS, 1993).

An estimated 3 million workers potentially may be exposed to benzene (IARC V.29, 1982). Exposure may occur during the production of benzene or during the use of substances containing the chemical as an ingredient or contaminant. In the National Occupational Health Survey (NOHS), conducted by NIOSH from 1972 to 1974, an estimated 1,495,706 workers were exposed to benzene in the United States (NIOSH, 1976). The National Occupational Exposure Survey (NOES), conducted by NIOSH from 1981 to 1983, estimated 272,300 workers potentially exposed to benzene (ATSDR, 1997-K007). Occupational exposure levels usually do not exceed a time-weighted average of 15 mg/m^3; they may be higher in some industrially developing countries (IPCS, 1993).

In a recent study, benzene was detected in 60% of car mechanics and 93.9% of road tanker drivers. The median concentrations were 0.14 and 0.68 mg/m^3, respectively. Furthermore, 6.1% of car mechanics and 33% of road tanker drivers were found to be exposed to more than 0.3 ppm of atmospheric benzene, the limit suggested by the ACGIH. The road tanker drivers were found to be primarily exposed to benzene through inhalation, whereas the car mechanics were particularly exposed via dermal contact. The loader is exposed to the fumes escaping from the manhole when he checks the level in the tank (Javelaud et al., 1998). Average exposure to benzene during top loading is 6.1 mg/m^3 and during bottom loading is 1.4 mg/m^3 (IARC V.45, 1989). Car mechanics are primarily exposed to benzene during the adjustment of direct fuel injection systems (Nordlinder and Ramnas, 1987). The benzene concentration in the breathing zone during this type of work has reached 1.1 ppm (3.5 mg/m^3) (Laitinen et al., 1994). The same results were found in a cross-sectional exposure survey conducted in Fairbanks, Alaska. All mechanics had higher postshift blood benzene concentrations than did nonmechanics—that is, drivers and other garage workers. The levels were significantly increased during the workshift for the former (during the suspension of the oxygenated fuel program) versus the latter, suggesting that the work activities of mechanics, who were mainly exposed to raw gasoline and solvents, resulted in greater benzene exposure than the activities of mechanics, who were largely exposed to motor vehicle exhaust (Moolenaar et al., 1997).

General population exposures to benzene are not correlated with industrial or vehicular emissions. Emission sources comprise 82% cars, 14% industry, 3% personal and home, and 0.1% cigarettes; benzene exposures of the general population comprise 40% from cigarettes, 18% each from personal activities and car exhaust, 16% from home sources, 5% from environmental tobacco smoke, and 3% from industry. Average daily benzene air intake of urban and suburban residents is estimated to be 180 to 1,300 µg. Intake from drinking water has been estimated at 0.2 µg/day (ATSDR, 1997-K007).

REGULATIONS

CPSC has withdrawn its proposed ban of consumer products, except for gasoline and laboratory reagents, that contain benzene as an intentional ingredient or as a contaminant at 0.1% or greater by volume. The decision to withdraw the rulemaking was based on CPSC findings that benzene is no longer used as an intentional ingredient in consumer products and that the contaminant levels remaining in certain consumer products are unlikely to result in significant consumer exposure to benzene vapor. A labeling regulation established for products containing more than 5% benzene and a safety packaging requirement for paint solvents and thinners containing 10% or more of petroleum distillates, such as benzene, remain in effect. CPSC has prepared and distributed "School Science Laboratories—A Guide to Some Hazardous Substances" to high school laboratories throughout the states. This document indicates that benzene is a carcinogen and that the hazards posed by its use in the laboratories may be greater than its potential usefulness, therefore recommending that it not be used or stored in schools.

EPA regulates benzene under the Clean Air Act (CAA), Toxic Substances Control Act (TSCA), Clean Water Act (CWA), Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), Superfund Amendments and Reauthorization Act (SARA), Food, Drug, and Cosmetic Act (FD&CA), Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), and Resource Conservation and Recovery Act (RCRA). EPA has listed benzene as a hazardous air and water pollutant and a constituent hazardous waste. EPA has assessed emission standards for ethylbenzene plants, benzene storage and fugitive emissions, and coke by-product plants. Under CWA, a reportable quantity (RQ) of 1000 lb and a maximum contaminant level (MCL) of 0.005 mg/L for benzene in primary drinking water have been set. Benzene is subject to reporting requirements under SARA and health and safety data reporting under TSCA. The SARA threshold planning quantity (TPQ) for benzene is 500/10,000 lb. Under RCRA, the final CERCLA RQ is 10 lb for benzene. FIFRA established a voluntary cancellation of registered products containing benzene as an active ingredient. Under FD&CA, EPA requires labeling on pesticides containing benzene as an inert ingredient. RCRA designates benzene as a hazardous constituent of waste and is subject to reporting requirements (regulatory level, 0.5 mg/L; hazardous waste number, U019). FDA regulates benzene as an indirect food additive under FD&CA. FDA also limits the amount of benzene in bottled water (0.05 mg/L). NIOSH recommended that exposure be reduced to 0.1 ppm as an 8-hr time-weighted average (TWA) with a 1-ppm ceiling. The NIOSH Pocket Guide to Chemical Hazards (1994) lists the recommended criteria for the TWA for up to a 10-hr work day during a 40-hr work week for benzene at 0.1 ppm and a 1 ppm ceiling concentration. OSHA lowered the standard of 10 ppm to establish an emergency temporary standard of 1 ppm as an 8-hr TWA, with a 5-ppm ceiling. A final standard establishing the temporary standard as the PEL was overturned by the U.S. Supreme Court. Subsequently, the OSHA regulation reverted to 10 ppm. OSHA received a petition requesting an emergency temporary standard that would reduce benzene exposure to 1 ppm. It denied the petition but published a Request for Information and Regulatory Schedule. OSHA later proposed to reduce the PEL to 1 ppm as an 8-hr TWA, which was subsequently promulgated. It also regulates benzene as a chemical hazard in laboratories under the Hazard Communication Standard. Regulations are summarized in Volume II, Table A-8.